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Abstract
A Web-Based Library and Algorithm System for Satellite and
Airborne Image Products
N00014-09-C-0553

This effort delivered the ability to produce bathymetry, bottom typing, and water-column optical property estimates from multispectral and hyperspectral imagery products in Very Shallow Waters (VSW). The VSW is a very different remote sensing environment relative to Deep Water (DW) environments, and requires special algorithms to retrieve these environmental products. The algorithms and software transitioned in the deliverables are based on an optimized spectral matching technique. This technique starts with the creation of estimates of spectral remote sensing measures for millions of possible combinations of environmental conditions in the VSW. These estimates are compared to measured spectral remote sensing signals from any platform, e.g. boats, aircrafts, satellites. The selection of the best matching estimated remote sensing signal is then used to retrieve the environmental conditions necessary to create that estimated signal, i.e. bathymetry, bottom type, and water column inherent optical properties.

This effort supports Navy METOC personnel in their ability to create in-house hyperspectral and multispectral imagery products, and warfighter-support imagery products. The deliverables here are transitioning VSW algorithms developed by Dr. Curtis D. Mobley at Sequoia Scientific, Inc., and Dr. Paul Bissett at FERI, under other 6.1/6.2 program funding.

A Web-Based Library And Algorithm System For Satellite And Airborne Image Products

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LONG-TERM GOALS

The focus of this effort is to create a managed library appliance that supports the Navy METOC personnel in their ability to search for in-house hyperspectral and multispectral imagery products, and provide algorithms that create bathymetry estimates from those imagery products on-demand.

OBJECTIVES

This one-year effort seeks to deliver an image library system that handles terabytes of imagery products with a simple and easy to use index, search, discovery, and delivery functionality. Further, this image library will have an algorithm interface that will allow viewers to “order” an image transformation of their choice, on-demand. We seek to work with a navy customer to place the library system in operational use for satellite and aircraft imagery products.

APPROACH

The Navy has a myriad of satellite and aircraft imaging systems to support ISR and METOC goals. These systems produce petabytes (PB; 10^{15} bytes) of imagery and imagery products per year. These imagery products are created worldwide, everyday, with varying time and space resolutions, resulting in thousands of daily products. The selection of any imagery product, or set of imagery products, to support a specific mission is hampered by the inability to quickly and efficiently find the required data. To efficiently find these high-value products, they must be archived in a library system that can rapidly search, discover, and deliver the required information to the intelligence/METOC officer.

Once the imagery product is found, it must be delivered to the analyst or operator. However, these imagery and map products may be very large. A single image over a small area (10-100s of square kilometers) may be 10-100s of gigabytes (GB; 10^9 bytes) in size. Transport of these large imagery products over the internet (or other secure networks) may not be possible because of the bandwidth

available between the product library and the analyst. Yet, the information contained in the product still needs to be communicated to the downstream analyst or operator, otherwise the value of the imagery product is lost. While the bandwidth restrictions may be unavoidable, the effective communication of the required ISR/METOC information may still be possible if the size of the product is reduced, or if the analysis of the product is completed before transport via the network.

The reductions in image size or the server-side rendering of the image product into an intelligence product (e.g. run an algorithm on the image and send only the results) are the most frequent forms of image customization prior to delivery. However, this precludes any form of interaction by the analyst to request changes in the imagery products resulting from changing conditions in the field. This limits the ability of the analyst to be “flexible” in relationship to field or operational conditions, and reduces the overall value of the imagery systems. In other words, if every new request for a slight alteration in the product requires hours or days of work, then the product is less likely to be useful during critical times of operation. To be truly successful, an imagery library system would be combined with the ability to customize the imagery products into high-value derivative maps on-demand. When combined with rapid search capabilities, these customization capabilities would accelerate the time-to-use of high-value imagery products, increasing the value of the products, as well as reducing the risk of ineffective product results.

This applied research effort builds upon previous basic and applied research efforts in the development of value-added products from multi- and hyperspectral imaging systems. It specifically seeks to address the issue of search, discovery, and delivery of high-value satellite and aircraft imagery data through internet-enabled systems. It also seeks to enable the on-demand customization of imagery products through the ingestion of specialized image transformations (e.g. algorithms) into the library system.

Objectives

- (1) Deliver an image library system that handles terabytes of imagery products with a simple and easy to use index, search, discovery, and delivery functionality.
- (2) Develop a transformation and algorithm interface for the library system that will allow viewers to “order” the transformation of their choice, on-demand.
- (3) Work with a navy customer to place a library system in operational use for satellite and aircraft imagery products.

Image Library System

The Florida Environmental Research Institute (FERI) has licensed and transitioned its library hyperspectral system for imagery and mapping products to WeoGeo, Inc. FERI works closely with WeoGeo in continuing to develop new capabilities for the library system. In this case, we at FERI will start with the basic implementation of the WeoGeo Library Appliance, and develop the new capabilities required for on-demand transformation and algorithm services.

The WeoGeo Library Appliance is a geospatial network appliance specializing in the web-hosting of high bandwidth mapping products. Designed to efficiently search, sort, customize, and deliver an enterprise’s product within seconds of a User’s entry into the system. This system easily handles

terabyte (TB) size raster imagery products including color and color-infrared aerial imagery, HyperSpectral Imagery (HSI), LiDAR, and satellite imagery.

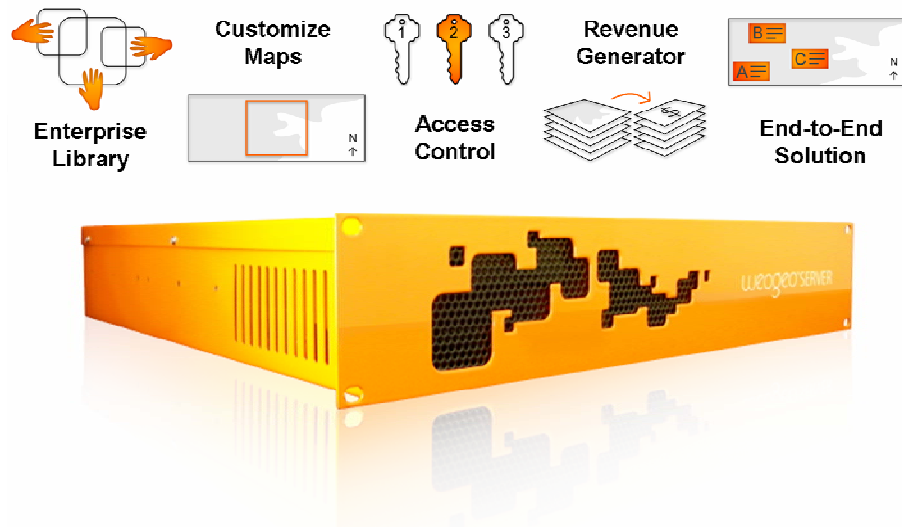


Figure 1. The WeoGeo Library Appliance is a network appliance that provides full hyperspectral imagery archival and distribution support.

The focus of the Library Appliance is to provide quick, efficient access to representations of the full layered, spectral, and spatial resolution data products. This focus allows the Appliance to provide rapid web-based search, sort, and selection capabilities over reduced bandwidth connections. Once a product has been selected, the User is provided with the additional selection options that optimize the product delivery of information layers (e.g. color bands), spatial resolutions, and/or total geographic extent (i.e. geo-clipping). Upon completion of the final product selection, the User's customized map is rapidly produced, completely independent of human intervention, and placed in a unique FTP folder available only to the user with their individual login credentials.

WeoGeo Library's unique features include:

- (1) A rolling panel feature that allows for the entire search, sort, selection, and order to be accomplished in the same window. The user never leaves the primary window that was entered.
- (2) The ability to search from the world to a city within a single viewing point, with data availability graphically given in the highest zoom window.
- (3) Searching and sorting by key words, locations, provider, projection, data type, map type, etc.
- (4) A What-You-See-is-What-You-Get (WSYWYG) capability that provides the user/buyer the ability to see exactly the mapping data they are going to order.
- (5) Direct support for 3-D viewers such as Google Earth and NASA World Wind, so that users may relate these data sets with other sets not available on the WeoGeo Server.
- (6) Direct support of FDGC compliant metadata files.
- (7) Email notification of request acceptance and data availability.
- (8) Data set security provided by unique login credential, which allow data sets to be grouped for different client sets and login capabilities.
- (9) Data request history is maintained for each user for email notification of data product updates, as well as easy reorder of additional products.

- (10) Batch processing of data sets for easy upload and maintenance with conversions of multiple projection and datums on-the-fly to user specification.
- (11) Upload of any ortho-rectified raster product in seconds to minutes with live access back to field deployed teams over reduced bandwidth internet connections. Ideal for DoD, DHS, FEMA, or NOAA event response teams deployed in multiple locations following a critical event.

Objective 1 – We will deliver a Library Appliance that can inventory, index, search, and deliver Naval-relevant imagery and imagery products.

Enabling Transformations and Algorithms

The WeoGeo Library currently offers limited customization to a select group of raster file types. These file types include JPEG, TIFF/GeoTIFF/BigTIFF, ENVI BIL/BSQ/BIP, ERDAS IMG, and ESRI BIL. Datasets of these types can be requested with the following customizations: geographic clipping/cropping, spatial re-sampling, band/layer selection, output data type format, and output datum and projection. The current interface for making these requests can be seen in Figure 4. All other file types are inventoried and delivered in their native file format.

Ideally, customization options should not be limited to a select group of raster formats. Vector data sets, profile measurements, and elevation data (e.g. LiDAR) would all be better served if they could be customized prior to their delivery. Each of these data sets types would have their own customization options and associated metadata. For example, CTD profiles have a geographic component, and it would be desirable to be able to subsection the profile by time or depth prior to delivery of the profile to an end-user.

Furthermore, user demanded customization of the data products might be more than just simple subsections of the data. These requests could be more complex, such as to run an algorithm like a spectrum matching approach to retrieve Inherent Optical Properties (IOPs) from hyperspectral imagery. These types of data transformations increase the value of the imagery product, while at the same time reducing the data volume and bandwidth requirements for transport via the internet.

The current means of handling the limited data customization may be seen in Figure 2. The viewing and selection operations seen in Figure 2 will need to be redesigned and replaced in order to make it flexible enough to handle other data transformations and algorithms. FERI will design the Naval-relevant template for WeoGeo, with a specific implementation of the spectrum matching approach to inverting hyperspectral imagery created by Drs. C. Mobley (Sequoia Scientific) and P. Bissett (FERI).

Objective 2 – We will design and create the ability to transform imagery products via the Library Appliance, with the specific use of the spectrum matching algorithms developed by Sequoia Scientific and FERI.

Testing and Implementation of Library

This project will result in the delivery of a WeoGeo Library with algorithm capabilities to an operational Naval partner. Our target partner is the METOC Sensing Programs Transitions & Integration at the Naval Meteorology and Oceanography Command (NAVO). We will try to work closely with T. Bowers, Commander of that operational group. We will also work closely with Naval

Research Laboratory partners at the Stennis Space Center and in Washington, DC to provide pathways for their algorithms to be incorporated into the NAVO WeoGeo Library.

Objective 3 – We will deliver of the spectrum matching algorithm, code, and user guides to a Navy transition partner for testing and implementation within an operational environmental.



Figure 2. Current customization screen for imagery products on WeoGeo Library Appliance. The data Preview Panel (panel 4 of the data selection process) provides basic metadata and access to enhanced descriptions of the data product. The Customize Panel (panel 5 of the data selection process) provides the data customization parameters for spatial resampling, band selection, file format, data projection, and geospatial clipping

WORK COMPLETED

Objectives 1 and 2 have been completed. Figures 3 and 4 show the web-page parameter selection screens for the kNN algorithm.

Workspace - kNN.fmw (Job Submitter)

Description: bold text is permitted.

Run workspace with the following parameters

☐ Email results to:

Parameter Prompt	Value
job_token	<input type="text"/>
look_up_table	<input type="text" value="/usr/local/bin/sample/look_up_table"/>
wavelengths	<input type="text" value="/usr/local/bin/sample/wavelengths"/>
Specify which field will make up the class	<input type="text" value="DEPTH"/> ...
Set a depth limit.	<input type="text" value="10"/>
Override default behavior (set all pixels > 1.0 to 0)	<input type="text" value="False"/> ...
Number of neighbors	<input type="text" value="50"/>
Use regression instead of classification	<input type="text" value="True"/> ...
Weighted KNN	<input type="text" value="True"/> ...
Available metrics	<input type="text" value="MANFATTAN"/> ...
Create floating point bil (default:short)	<input type="text" value="True"/> ...
Name for the new product	<input type="text" value="kNN Product"/>

Figure 3. Parameter selection screen for the kNN algorithm on the ONR WeoGeo Library Appliance. The screen allows the user to select the wavelengths to be used for the spectrum matching, matching result, depth limit, number of neighbors, and statistical metrics to determine best match between the database spectrum and the image spectrum.

Objective 3 was modified from its original intent. New security concerns and procedures within NAVO greatly limited their ability to accept a hardware search and imaging processing appliance. We sought advice and a new Naval-accepting agent to accomplish the overall objectives of this contract.

The fundamental objective in this effort was to provide Navy personnel with the ability to rapidly produce mapping products from HSI and MSI imagery. We received clearance from our ONR program manager to recode the spectrum matching code into a stand-alone software deliverable. This deliverable was to include the spectrum matching code, user guide, and example HSI imagery to demonstrate the software.

On May 12, 2011, the “Comprehensive **R**eflectance **I**nversion based on **S**pectrum matching and **T**able **L**ookup” (CRISTAL) software, as well as its User Guide and Technical Documentation was shipped to Dr. Alan Weidemann of NRL-SSC (Hydrological Optics Sensors and Systems - Code 7333). This software and documentation will enable Dr. Weidemann to process all the imagery expected to be processed under the original objectives of this effort.

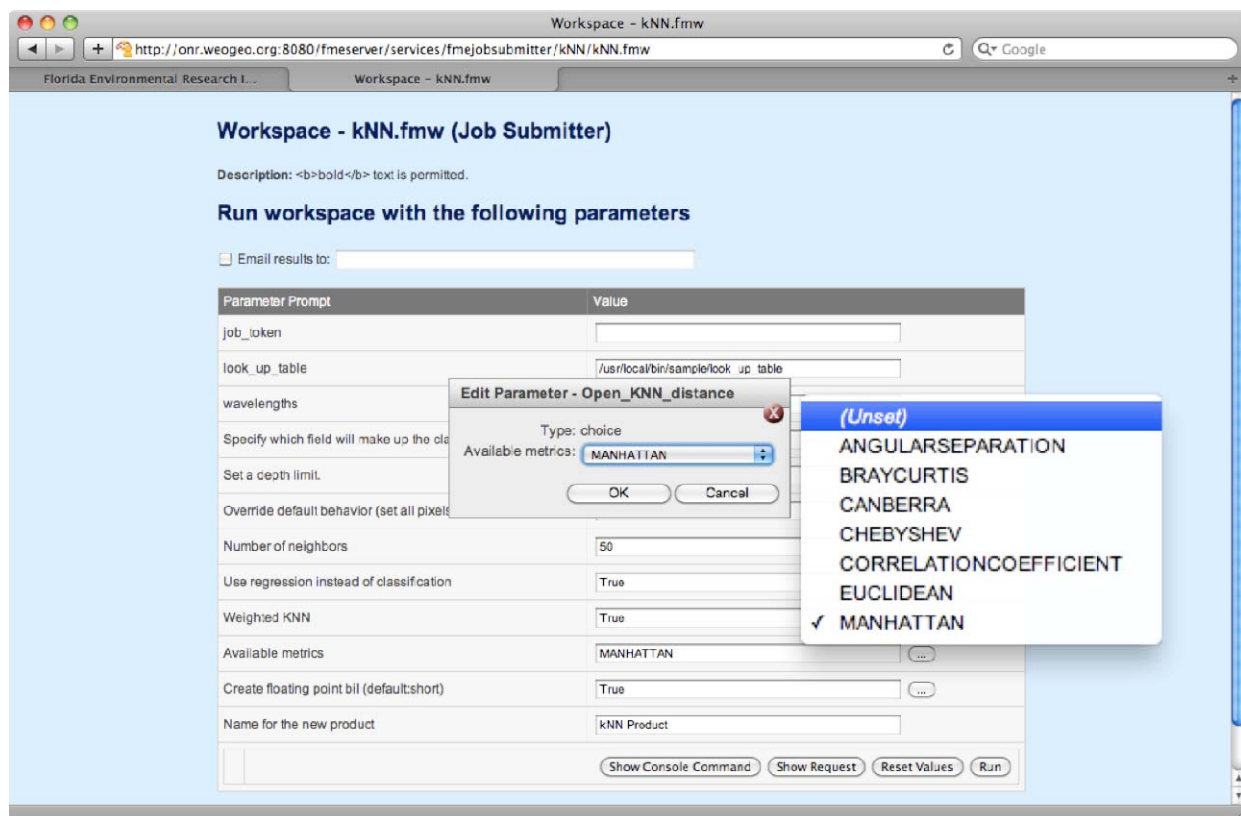


Figure 4. Parameter selection screen for the kNN algorithm on the ONR WeoGeo Library Appliance. This figure shows how drop down menus are used to select the parameters. In this example, the statistical metric to be used to match the spectrum will be Manhattan distance calculations between the database spectrum and the image spectrum.

IMPACT/APPLICATIONS

This effort delivered the ability to produce bathymetry estimation from multispectral and hyperspectral imagery products in Very Shallow Waters (VSW). It supports Navy METOC personnel in their ability to create in-house hyperspectral and multispectral imagery products, and warfighter-support imagery products, on-demand.

RELATED PROJECTS

This work is transitioning VSW algorithms developed by Dr. Curtis D. Mobley at Sequoia Scientific, Inc., and Dr. Paul Bissett at FERI, under other 6.1/6.2 program funding.